LANDFILL GAS UTILIZATION FEASIBILITY STUDY
PIKE COUNTY FORD BRANCH LANDFILL
PIKEVILLE, KENTUCKY

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DISCLAIMER

This feasibility assessment was prepared specifically for the Pike County Fiscal Court on behalf of the U.S. EPA Landfill Methane Outreach Program. Projections and findings are based on engineering judgment. The EPA and its contractors, EMCON and ERG, do not guarantee the quantity of available landfill gas or the financial feasibility, and no other warranty is expressed or implied. No other party is intended as a beneficiary of this work product, its content, or information embedded therein. Third parties use this report at their own risk. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

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SECTION 1

INTRODUCTION

OBJECTIVES

The EMCON/ERG Project Team (EMCON/ERG), on behalf of the U.S. Environmental Protection Agency's (EPA's) Landfill Methane Outreach Program (LMOP), has assessed the feasibility of using landfill gas (LFG) from the Pike County Ford Branch Landfill. The purpose of this report is to evaluate the LFG generation and recovery potential at the Pike County Ford Branch Landfill and provide a preliminary evaluation of the approximate cost of recovering the energy present in the gas.

INTRODUCTION

Landfills produce LFG as organic materials decompose under anaerobic conditions. LFG is composed of approximately equal parts of methane (CH_4) and carbon dioxide (CO_2) with trace concentrations of other gases, including non-methane organic compounds (NMOCs). Landfill gas can be an asset when it is used as a source of energy. It is classified as a medium-Btu gas with a heating value of 350 to 500 Btu/scf, approximately one-half that of natural gas.

LFG can often be used in place of conventional fossil fuels in certain applications. Landfill gas is inherently a low-pollution fuel with respect to nitrogen oxides (NOx), carbon monoxide (CO), unburned hydrocarbons (HC), and volatile organic emissions. The flame temperature that results from the burning of LFG is generally low, so NOx emissions are generally about 70% lower than those of natural gas combustion. The flame temperature, however, is not so low as to aggravate HC or CO emissions. Emissions from LFG combustion can be as low as 22 ppm of NOx, 5 ppm of CO, and 5 ppm of HCs. By using LFG to produce energy, landfills can significantly reduce their emissions of methane, a potent greenhouse gas. Use of LFG also avoids the need to generate energy from fossil fuels, reducing emissions of carbon dioxide (CO_2) and sulfur dioxide (SO_2) from fossil fuel combustion.

LANDFILL BACKGROUND

The Pike County Ford Brach Landfill first opened in February 1993 and expects to operate until at least 2010. The Pike County Fiscal Court operates the landfill, which spreads across 56 acres and is estimated to contain about 594,000 tons of waste, as of August 2001. The waste in the landfill is about 85 percent municipal solid waste and 15 percent construction and demolition waste. On average, the landfill is approximately 150 feet deep with waste. The Pike County Landfill has a flexible membrane liner (FML) and a flexible membrane cap. The second phase of the landfill was closed in 1996 and construction of the fourth phase of the landfill was begun in 2001. The leachate collected from the landfill is handled by the local publicly owned treatment works (POTW).

To ensure compliance with Subtitle-D regulations pertaining to LFG migration, the landfill has a passive venting system. This is the only LFG system that is currently in place at the landfill. The installation of any gas collection system in the future will require drilling into the waste.

At present, the landfill would *not* be eligible for Section 29 federal tax credits if it began generating usable energy from LFG. Due to its relatively small size, it is also *not* subject to the control provisions of the New Source Performance Standards/Emissions Guidelines (NSPS/EG).

SECTION 2

LANDFILL GAS GENERATION AND RECOVERY

To estimate the potential LFG recovery rate for the landfill, EMCON/ERG used EPA's Landfill Gas Emissions Model (LandGEM) software, which employs a first-order decay equation. For comparison purposes, EMCON also used its proprietary LFG Estimation model to provide additional insight into the LFG generation and recovery potential of the site. The EMCON LFG estimation model also has some additional features that can make it a useful tool to use for comparison purposes.

LANDGEM MODEL DESCRIPTION

The LFG generation model requires a few basic inputs such as the landfill's dates of operation and the amount of waste currently in place in the landfill. The model employs a first-order exponential decay function. This function is based on the idea that the amount of LFG generated from solid waste reaches a peak after a certain time lag for methane generation. The model assumes a one-year time lag between placement of waste and LFG generation. The model also assumes that for each unit of waste, LFG generation decreases exponentially (after the one-year time lag) as the organic fraction of the waste is consumed.

For sites with known (or estimated) year-to-year solid waste acceptance rates, the model estimates the LFG generation rate for a given year using the following equation, which is published in Title 40 of the U.S. Code of Federal Regulations (CFR) Part 60, Subpart WWW.

$$Q_M = \sum_{i=1}^{n} 2\,k\,L_o\,M_i\,(e^{-kt_i})$$

Where:

Q_M = maximum expected LFG generation flow rate (m^3/yr);

$\sum_{i=1}^{n}$ = sum from opening year+1 (i=1) through year of projection (n);

k = methane generation rate constant (1/yr);
L_o = methane generation potential (m^3/Mg);
M_i = mass of solid waste disposed in the i^{th} year (Mg);
t_i = age of the waste disposed in the i^{th} year (years).

The above equation is used to estimate LFG generation for a given year from all waste disposed up through that year. One may develop multi-year projections by varying the projection year and re-applying the equations. The point of maximum LFG generation normally occurs in the closure year or the year following closure (depending on the disposal rate in the final years).

EMCON MODEL DESCRIPTION

The EMCON model shares the same origins as the LandGEM model. EMCON, however, has added variables and made modifications based on its experience with landfill gas recovery. The EMCON model incorporates information about the landfill's waste stream, the LFG generation potential of the individual waste stream components, as well as the moisture, temperature, and associated climatic factors of the disposal area. The EMCON model's output is shown in Appendix A.

ESTIMATED LFG RECOVERY

As part of the estimation of the amount of LFG that one could expect to actually *recover* from the site, an approximate recovery efficiency rate was applied to the LFG generation rates provided by the models. The Pike County landfill has a flexible membrane liner and cap. Based on these conditions, an 85-percent collection efficiency was estimated.

MODEL INPUTS

Table 2-1 shows the information about past and expected future municipal solid waste quantities that was provided by the Pike County Fiscal Court. The projected closure year for the landfill is 2010, according to the site's engineering firm. These waste quantities were used to develop the LFG recovery estimates in the EPA's LandGEM model. Note that although the total capacity of the landfill is estimated to be 1.25 million tons, about 15 percent of waste is construction and demolition waste, which has little methane generation potential. Therefore, only 85 percent of the capacity (1.06 million tons of waste) was used to estimate maximum potential LFG generation rates.

MODEL RESULTS

Based on the inputs shown in Table 2-1, the models produced the estimated LFG recovery flow rates shown in Table 2-2 and graphically presented in Figures 2-1 and 2-2. (Note that the table and figures show potential gas recovery rates rather than gas generation rates. The recovery rate is assumed to be 85 percent of the predicted gas generation rate.)

The results from the two models are very similar except that the LandGEM model predicts peak LFG generation and recovery in 2010 and EMCON predicts peak LFG generation and recovery about 3 years later in 2013. As a result, the LandGEM model results are within the EMCON range for all of the years modeled after 1999 except for the years 2012 to 2018. During the period 2012 to 2018, the LandGEM results are close to the lower limit of the range predicted by the EMCON model. In general the EMCON model predicts a lower gas flow in the early years and it predicts a somewhat quicker reduction of gas flow over the later years. As shown in the table and figures, the models predict that the highest gas recovery rates (perhaps between 300 and 470 scfm) occur in the period from 2010 through 2013.

Table 2-1. Annual Municipal Solid Waste Quantities Received

Year	Tons of Waste	Year	Tons of Waste
1994	88,800	2010	41,200
1995	48,400	2011	0
1996	52,200	2012	0
1997	41,600	2013	0
1998	60,200	2014	0
1999	60,100	2015	0
2000	56,600	2016	0
2001	62,800	2017	0
2002	68,900	2018	0
2003	68,800	2019	0
2004	68,700	2020	0
2005	68,900	2021	0
2006	68,800	2022	0
2007	68,800	2023	0
2008	68,900	2024	0
2009	68,800	2025	0

Table 2-2. LFG Recovery Estimates

Year	Accumulated Tons of Municipal Solid Waste	LFG Recovery Potential based on LandGEM Model (scfm)	LFG Recovery Potential based on EMCON Model (scfm)
1994	88,800	37	10-15
1995	137,200	55	18-26
1996	189,400	75	31-46
1997	231,000	89	49-73
1998	291,200	111	73-109
1999	351,300	131	100-150
2000	407,900	149	127-190
2001	470,700	170	150-225
2002	539,600	192	171-257
2003	608,400	213	192-288
2004	677,100	233	212-319
2005	746,000	252	232-348
2006	814,800	271	249-373
2007	883,600	289	264-397
2008	952,500	306	278-417
2009	1,021,300	322	290-435
2010	1,062,500	327	300-450
2011	1,062,500	314	310-466
2012	1,062,500	302	313-470
2013	1,062,500	290	314-471
2014	1,062,500	279	310-465
2015	1,062,500	268	300-450
2016	1,062,500	257	283-425
2017	1,062,500	247	262-393
2018	1,062,500	237	239-359
2019	1,062,500	228	218-328
2020	1,062,500	219	201-302
2021	1,062,500	210	185-278
2022	1,062,500	202	171-256
2023	1,062,500	194	157-236
2024	1,062,500	187	145-217
2025	1,062,500	179	133-200

Note: These projections have been prepared specifically for the Pike County Fiscal Court on behalf of the U.S. EPA Landfill Methane Outreach Program. They are based on engineering judgment and represent the standard of care that would be exercised by a reasonable professional experienced in the field of landfill gas projections. EMCON/ERG does not guarantee the quantity of available landfill gas, and no other warranty is expressed or implied. No other party is intended as a beneficiary of this work product, its content, or information embedded therein. Third parties use this report at their own risk. EMCON/ERG assumes no responsibility for the accuracy of information obtained from, compiled, or provided by other parties.

Figure 2-1. Landfill Gas Generation And Recovery Projections For the Pike County Landfill Based On the LandGEM Model

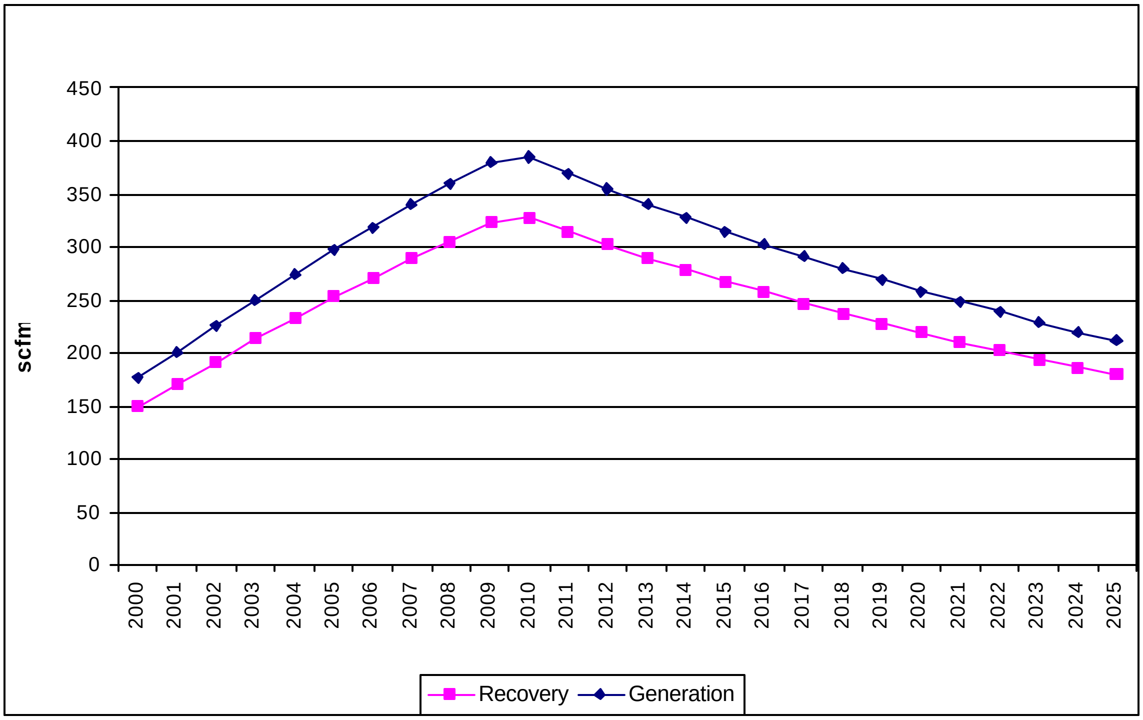
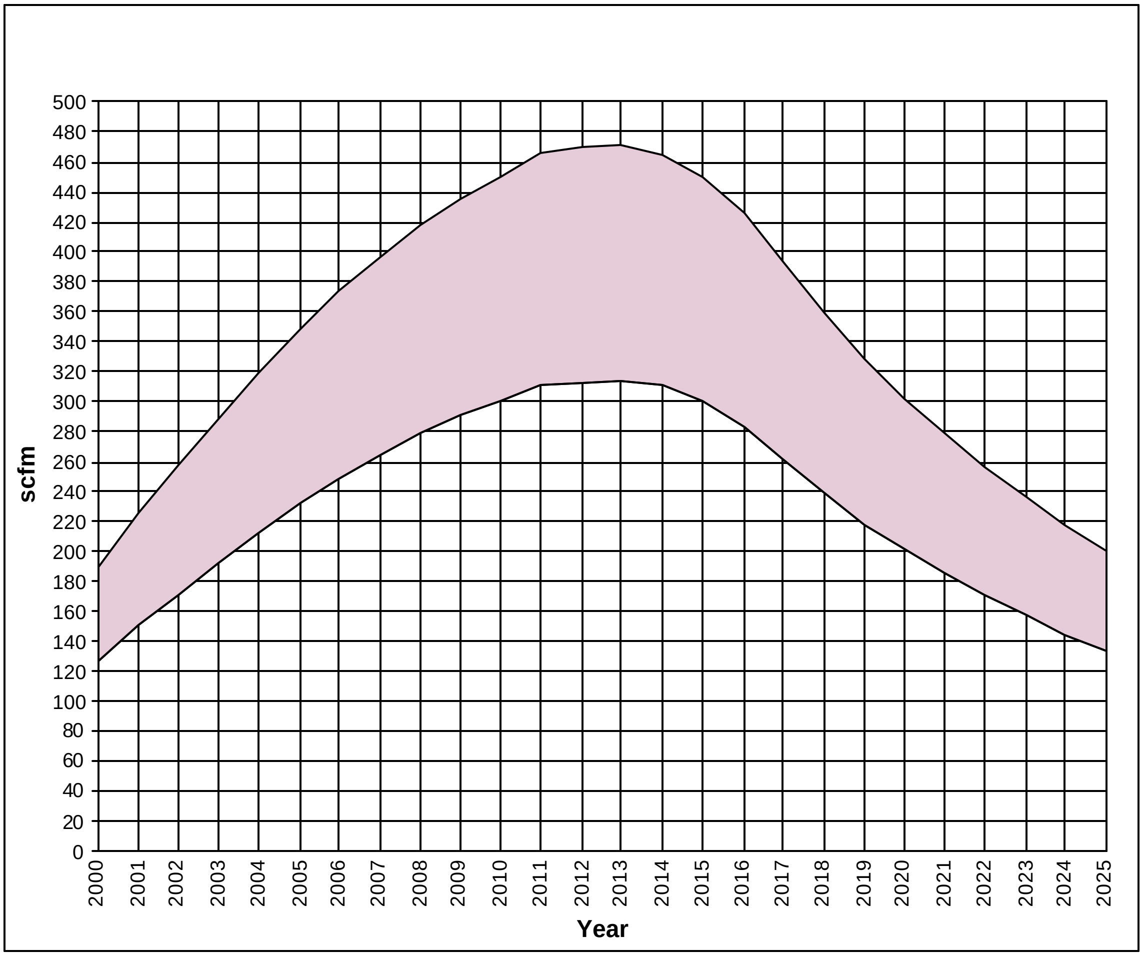


Figure 2-2. Upper And Lower Limits Of Landfill Gas Recovery Projections For The Pike County Landfill Based On The EMCON Model



GAS GENERATION AND RECOVERY CONCLUSIONS

Over the 10 year period from 2002 to 2012, the LandGEM Model predicts a minimum LFG recovery rate of approximately 192 scfm in the year 2002, while the EMCON LFG estimation model predicts a recovery rate of 171 to 257 scfm in the same year. Gas recovery rates are likely to remain at or above this level for approximately the next 20 years. The Pike County Landfill has long term potential for landfill gas generation and recovery because it is still open and is still receiving waste.

SECTION 3

END USE AND ECONOMIC EVALUATION

This section presents information about three potential end uses for the LFG collected from the Pike County Landfill and their economic viability:

- Running a small internal combustion (IC) engine to generate electricity;
- Heating an on-site greenhouse;
- Transferring the collected medium-Btu LFG to a natural gas pipeline.

Economic evaluations for each option have been completed, taking into account capital costs for equipment and installation, annual operational costs, and the installation of a gas collection and control system (GCCS) necessary to extract and convey the LFG to end-use equipment. For the IC engine and the medium-Btu pipeline options, the economic analyses were conducted using the E-Plus software. For the purpose of comparison, economic evaluations using EMCON's internal economic analysis software were also performed for these options. For the greenhouse heating option, the economic analysis was performed using only EMCON's software because no mechanism currently exists in E-Plus for this type of option. Appendices B and C contain the detailed results of these analyses.

GAS RECOVERY FOR ALL OPTIONS

Since the landfill is currently under no regulatory obligation to install an active gas collection system, the LFG gas collection system (including gas well drilling) is included in the economic evaluation of each option. Additionally, it is assumed that the well field gas blowers and standby flare system would be located near any IC engine, greenhouse, or natural gas pipeline, thereby eliminating the need for any additional blowers to pump gas to the standby flare system. The GCCS and LFG supply costs were estimated as follows:

- The E-Plus model's estimate for the gas collection and control system (GCCS) is $501,249, including gas well drilling, flare, and blowers. This same cost is used in the EMCON software calculations.

- The LFG pipeline would be constructed of 6-inch diameter HDPE pipe and would be extended 1,000 feet to the combined blower, flare, and equipment location. The cost of these pipes and valves to divert gas to the flare is $25,000.

- Annual gas collection system operation and maintenance costs are included in the annual costs in the evaluation of each option.

For all three options, LFG must be collected and treated before it can be used. Moisture and particulates typically are removed through a series of filters, knockout vessels, and/or driers. Following this minimal level of gas cleaning, gas quality of 35 to 50 percent methane is typically available. This level of methane concentration is generally acceptable for use in a variety of equipment, including boilers and engines. Although most pieces of equipment are designed to handle natural gas that is nearly 100 percent methane, they can be modified to handle gas with lower methane content.

ELECTRICITY GENERATION WITH AN INTERNAL COMBUSTION ENGINE

One option for using LFG is the use of an internal combustion (IC) engine to generate electricity. If electricity is not required at the landfill, it can be distributed through the local power grid. This approach requires close cooperation with the electric power utility. Information is provided here about selling electricity to the grid system. It is important to note that the ultimate feasibility of this option depends on the electricity purchase rate paid by the local electric utility. Economies of scale tend to make this option more feasible as gas generation rates increase. Since this landfill produces a low gas flow, electrical sales to a utility company may not be a financially viable option. On-site use of electricity is potentially a more viable option. Although there are only a few on-site activities requiring electricity, they might provide a use for low-flow LFG.

Internal combustion (IC) engines are the most commonly used conversion technology in LFG applications. They are stationary engines, similar to conventional automobile engines. They can use medium-Btu gas to generate electricity. While they can range from 30 to 2,000 kW, IC engines associated with landfills typically have capacities of 400 to 1,000 kW. IC engines are a proven and cost-effective technology that can use LFG as a fuel, provided that the LFG has a minimum energy content of 450 Btu/ft^3. Their flexibility, especially for small generating capacities, makes them a convenient option for smaller landfills.

Impurities in landfill gas can cause corrosion in IC engines. Impurities may include chlorinated hydrocarbons that can react chemically under the extreme heat and pressure of an IC engine. This problem is generally solved by pretreatment (primarily moisture removal) of LFG before it reaches the IC engine. Other impurities of concern include silicon-containing compounds (i.e., siloxanes), which oxidize during combustion and form a sand-like compound. This type of abrasive byproduct can cause significant damage to IC engines. Another consideration is that IC engines are relatively inflexible with regard to their air-fuel ratio, which may fluctuate along with the quality of the LFG. Some IC engines also produce significant nitrogen oxide (NOx) emissions, although designs exist which minimize this problem.

A small IC engine could be a viable option for this landfill. A range of small IC engine sizes are available and different sizes could be selected depending on how the landfill owners want to match the engine size to the LFG flowrate, which will vary over the life of the project. The owners could select a smaller engine that could be operated at full capacity over the life of the project. Alternatively, they could select a larger engine that would operate at full capacity only over a few years of peak LFG generation and recovery rates and at less than full capacity in other years. However, the viability of an IC engine alternative and the optimal size of an IC engine can be more accurately assessed after the LFG gas collection system is in place. The electricity generated with an IC engine may either be sold to a local electric utility or used on-site.

The E-Plus model evaluated costs for a 933 kW IC engine, which would operate at an average load of 76% over the 15-year project life, but at full load during years of peak LFG production. The capital cost for this option is approximately $1,497,000, including the purchase and installation of the engine, connection to the power grid, gas treatment, the container to house the engine, and the gas collection system. (See Appendix B.) The E-Plus model also predicts that the annual operation and maintenance cost for this option is $196,000 per year.

It is conventional to amortize the capital costs over a 10-year period or the lifetime of the project rather than considering them as an expenditure made at a single point in time. The LFG generation models indicate that the site's gas recovery rates may be sufficient to supply the internal combustion engine's fuel needs for 15 years or more. Loan periods of 10 years are typical of the industry. Therefore, the capital cost for constructing the electricity generation power plant has been conservatively depreciated over 10 years.

Financial Results

The revenue potential from electricity generation and sales was estimated using an assumed sale price of $0.05 per kWh. The financial analysis provided by the E-Plus model is summarized below:

- Capital Cost = $1,497,000
- Annual Operations and Maintenance (O&M) Cost = $196,000
- Loan Rate = 8 percent
- Loan Period = 10 years
- Discount Rate = 12 percent
- Inflation Rate for Costs = 2.0 percent
- Net Present Value = $(515,000)
- Internal Rate of Return = 0 percent
- Simple Payback = 35 years

Based on the electricity sales priced of $0.05 per kWh, this preliminary analysis indicates that this project is not economically feasible. It has a negative net present value and the simple payback period (greater than 15 years) is longer than the expected period of the project based on the LFG generation rate. As shown in Appendix B, the electricity sales price that would be needed to exceed a 12 percent internal rate of return is $0.056 per kWh.

For the purpose of comparison, we also used EMCON's pro forma model to estimate the expenses and income of operating two smaller IC engines with LFG. The EMCON model produced results which were in general agreement with the results of the E-plus model. At a sales price of $0.05 per kWh, there was a negative net present value and a simple paypack period greater than the 15-year project life. However, if the electricity could be sold for the higher price of $0.07 per kWh, the project would be feasible with a projected positive net present value and a simple payback period of 6 years.

On Site Use of Electricity

We considered whether the landfill could use an IC engine to generate electricity for internal use. However, based on the landfill's electricity bills, its electricity use is quite low. The landfill could use only a small fraction of the electricity that could be generated by its LFG for internal use. Thus, in order to use all of the site's LFG, electricity would need to be sold. For this reason, the internal use option was not examined in detail.

GREENHOUSE HEATING

Other landfill gas-to-energy projects have found LFG to be practical and cost effective to heat a greenhouse located near the landfill. Based on the available data, a greenhouse is a viable option for the Pike County Landfill. Outlined below are some of the primary considerations for estimating the energy requirements of a greenhouse. Because the E-Plus software does not contain a mechanism for evaluating the feasibility of heating a greenhouse, we used the EMCOM pro forma model for this analysis.

Greenhouse Energy Requirements

While electricity is commonly used to power fans, lights, and other miscellaneous equipment, fuels such as oil, natural gas, and propane are typically burned to heat a greenhouse. A greenhouse's fuel needs depend on a number of factors:

- Crop type dictates the temperature that must be maintained. For example, carnations can tolerate temperatures in the low 50s, whereas roses require warmer temperatures.

- Geographic location influences the amount of energy necessary to maintain the optimal growing temperature for a crop. At colder, northern latitudes, it takes between 100,000 and 200,000 Btu per square foot (ft^2) of floor area per year to heat a greenhouse during the growing season. A University of California report (Reducing Energy Costs in California Greenhouses, Leaflet 21411) states that greenhouses use an average of 115,000 Btu/ft^2 of floor area per year. Considering that the Pike County Landfill is in the Appalachian foothills of eastern Kentucky, a heating requirement slightly above this average is expected.

- The kind of building materials used to construct the greenhouse, from glazing materials to ventilation systems, affect energy demand. Glass, rigid plastic, or plastic film used for walls and ceilings each have different thermal efficiencies which allow different amounts of heat loss.

Outlined below are estimates of the economics involved with using the LFG to heat a future greenhouse. These costs include collecting the gas and conveying it to the greenhouse. The cost assumptions for the collection system (listed earlier) are the only costs associated with getting the gas to the greenhouse. Also listed below (for informational purposes) are estimates of an appropriate greenhouse size and the costs for greenhouse construction. Note that the costs of greenhouse construction are typically incurred by the company that plans to build and operate the greenhouse business, not by the landfill.

Preliminary Greenhouse Sizing

Based on the E-Plus and EMCON models, the landfill is expected to be able to recover a minimum of between 150 and 225 scfm of LFG in 2001, increasing to a maximum of about 300 to 450 scfm in 2010. From this information, it is determined that a greenhouse project could be supported by this landfill. A common greenhouse design and construction approach is to provide greenhouses that are constructed of multiple units of the same size. This provides some flexibility to the landfill owner. For this study we have assumed the greenhouse size would be 39 units of 22' x 96' (representing 82,368 ft^2 of floor space and 174,408 ft^2 of surface area). The greenhouse requires an LFG flow rate of approximately 230 scfm at 50 percent methane. Based on model estimates, this size of greenhouse should be supportable from about 2004 until about 2018. However, because of the uncertainty in landfill gas flow, it is suggested that further flow analyses be conducted once the collection system is completed. At that time it may be determined that a smaller or larger greenhouse is needed.

Preliminary Greenhouse Construction Costs

The EMCON/ERG team has gathered additional information from Jaderloon Company, Inc. (an LMOP partner and a greenhouse designer) on greenhouse heating requirements, sizes, and costs. Based on these data, a greenhouse of this size would cost $739,000 and installation costs and interest during construction would be approximately $980,000, for a total of $1,719,000.

For comparison, we also performed an analysis of greenhouse construction costs (based on a 1996 publication) that assumes a greenhouse with a floor area of 82,368 ft^2. We also assumed that the least expensive construction approaches are used. Table 3-1 summarizes the construction estimates.

TABLE 3-1. GREENHOUSE CONSTRUCTION COSTS

ITEM	COST ($\$/ft^2$)
Rigid Frame Wood Greenhouse	2.25
Site Prep/Driveway/Concrete Floor	4.05
Environmental Control (HVAC)	6.15
TOTAL (rounded)	12.45

The costs shown in this table were derived from Greenhouse Engineering, Aldrich, R.A. and Bartok, J.W., Northeast Regional Agricultural Service; Cornell University, Ithaca, NY, published in August 1996. The costs shown above were adjusted by an annual inflation rate of three percent over the costs provided by this source

The approximate total cost of greenhouse construction is calculated by multiplying the total square footage of floor area by the cost per square foot as shown below.

$$\left[82{,}368\ ft^2\right]\frac{\$12.45}{ft^2} \quad = \quad \$1{,}025{,}481$$

Thus, construction and installation costs are likely in the range of $1,025,000 to $1,719,000. Greenhouse construction firms can provide more accurate costs once more specific information is known about the types of crops to be grown and the proposed greenhouse's size, design, preferred building materials, and construction methods.

Heating System Cost Comparison

Although there can be yearly, monthly, or daily fluctuations, the US Department of Energy (DOE) projects natural gas prices for commercial customers will be approximately $5.00 per million Btu (MMBtu) for the next few years. Therefore, in order for the project to be feasible from an energy purchasing standpoint, the cost to supply the greenhouse with LFG must be less than $5.00 per MMBtu.

The costs for installing and operating the LFG collection system, but not the cost to construct the greenhouse, are included in the economic evaluation. Therefore, the costs that are relevant from a fuel supply standpoint are those associated with collecting the LFG and the equipment necessary to convey the LFG from the blower/flare station to the greenhouse.

The installed capital cost of the LFG collection and delivery system is approximately $526,000. It is conventional to amortize these costs over the lifetime of the project rather than considering them as an expenditure made at a single point in time. The LFG generation models indicate that the site's gas recovery rates would be sufficient to supply the greenhouse's heating needs until at least 2018. Therefore, the capital cost of the collection and delivery system has been conservatively amortized over a 10-year period, resulting in an annualized capital cost of $78,400 per year. The annual operating and maintenance costs of the collection and delivery system are $35,000 per year. Therefore, total annual costs to provide the greenhouse with LFG are $113,400 per year. (See Appendix C).

Based on the modeled gas recovery rate and preliminary greenhouse sizing information, the landfill can provide 230 scfm of gas for use to heat the greenhouse. The cost of providing the LFG to the greenhouse is $1.88 per MMBtu, an approximation based on the following calculation:

$$\left[\frac{\$113{,}400}{year}\right]\left[\frac{year}{525{,}600\min}\right]\left[\frac{\min}{230 ft^3 LFG}\right]\left[\frac{ft^3 LFG}{500 Btu}\right]\left[\frac{10^6 Btu}{MMBtu}\right]$$

$$= \$1.88 \text{ per MMBtu}$$

In other words, as long as the cost to purchase natural gas to heat the greenhouse is greater than \$1.88 per MMBtu, it is economically feasible to use LFG for greenhouse heating.

This LFG cost per MMBtu was calculated assuming that 230 scfm of LFG is used year round in the greenhouse. In fact, given the location in Kentucky, it is likely that the heat demand is seasonal. If you assume the greenhouse may only need to be heated for half the year, then the total amount of LFG used by the greenhouse each year might be only half as much as calculated. This would cause the cost per MMBtu to increase, but the cost would still be less than double the \$1.88 per MMBtu shown above. Even if the cost were up to \$3.76 per MMBtu, the cost of using LFG to heat the greenhouse would still be less than the cost of using natural gas. As indicated previously, the LFG recovery potential at the site will eventually diminish over time, even though it will be beyond the 15-year economic life of the project. One way to off-set this eventual reduction in LFG could be to use a boiler with "duel-fuel" capability. That is, a boiler that is capable of using LFG, as well as natural gas as a fuel source.

MEDIUM-BTU GAS PIPELINE

In some cases, the LFG can be injected into a natural gas pipeline system. However, natural gas pipeline systems typically transport high-quality gas that is over 95 percent methane. Therefore, prior to injecting the recovered LFG into such a system, it would generally need extensive treatment and processing to remove the carbon dioxide (CO_2) and other impurities to create a high-Btu gas. Processing the gas to meet strict quality specifications and high-Btu pipeline standards raises the cost of production because of the high gas compression and corresponding power consumption requirements. Due to the strict quality requirements there can also be operational issues associated with maintaining compliance with surface emissions or Subtitle-D requirements. As a result, this option is usually not economically viable especially for landfills with less than 8 million tons of waste. In contrast, the Pike County Landfill will hold a maximum of about 1 million tons of waste. However, in an environment of high natural gas costs, upgrading landfill gas to pipeline quality may be a profitable option.

For the Pike County Landfill, we used the E-PLUS model to evaluate the option of injecting medium-Btu gas into an adjacent natural gas pipeline with minimal pretreatment. Preliminary conversations indicate that the natural gas pipeline is likely to accept medium Btu gas (50% methane) from the landfill, without extensive processing and upgrading. The landfill should verify this before proceeding with the medium Btu gas sales option. Depending on the natural gas flowrate in the pipeline, injecting medium Btu landfill gas could lower the overall quality of the natural gas in the pipeline, which could affect the pipeline gas customers and necessitate a lower sales price for the pipeline gas. The cost analysis for the medium Btu gas option assumed the following cost elements:

- The installation of 250 feet of buried 8-inch diameter high-density polyethylene (HDPE) pipe to the existing natural gas pipeline

- A fuel skid consisting of a compressor to pressurize the LFG and a knock-out pot to remove moisture before inject the LFG into the pipeline.

- The installation of the GCCS to collect the gas.

The E-Plus model evaluated costs for transferring the medium-Btu LFG to a natural gas pipeline and determined that the capital cost for this option is approximately $529,000, including the purchase and installation of the connecting pipeline, the fuel skid, and the gas collection system. (See Appendix B.) The E-Plus model also predicts that the annual operation and maintenance cost for this option is $51,500 per year.

It is conventional to amortize these costs over the lifetime of the project rather than considering them as an expenditure made at a single point in time. Therefore, the capital cost for the GCCS, the fuel skid, and connecting to the natural gas pipeline has been depreciated over 10 years.

Financial Results

In recent years, the price of natural gas to commercial customers has been slightly more than $5.00 per million Btu and the price for industrial customers has been between $2.50 and $3.00 per million Btu. Based on DOE projections, prices are expected to stay close to these values in the next few years. Since the gas pipeline to which LFG would be transferred could serve a mix of commercial and industrial customers and because LFG is of lower quality than natural gas, we estimated the revenue potential from LFG sales using an assumed LFG sale price of $2.50 per million Btu. The financial analysis provided by the E-Plus model is summarized below:

- Capital Cost = $529,000
- Annual Operations and Maintenance (O&M) Cost = $51,500
- Loan Rate = 8 percent
- Loan Period = 10 years
- Discount Rate = 12 percent
- Inflation Rate for Costs = 2.0 percent
- Net Present Value = $486,500
- Internal Rate of Return = 45 percent
- Simple Payback = 6.6 years

Based on a LFG sales price of $2.50 per million Btu, this preliminary analysis indicates that this project is economically feasible. It has a positive net present value and the simple payback period (6.6 years) is shorter than the expected period of the project based on the LFG generation rate. However, if further processing of the LFG is required to remove CO_2 and increase the methane content prior to injection into the pipeline, these costs would increase significantly, and the option may not be feasible.

For the purpose of comparison, we also used EMCON's pro forma model to estimate the expenses and income of selling LFG to a natural gas pipeline. The EMCON model produced some what higher capital and annual costs, but was still in general agreement with the E-Plus model that the project appears feasible at a sales price of $2.50 per million Btu.

CONCLUSIONS

Based on the background information provided to EMCON/ERG, a sufficient amount of LFG should be generated at the Pike County Landfill to allow LFG recovery for use on a greenhouse project and this is the most feasible of the three options analyzed.

A project involving the injection of the medium Btu LFG into a natural gas pipeline may also be feasible, but additional technical issues presented by the lower Btu content of the LFG and the presence of impurities may need to be addressed before this option can be fully evaluated.

A project using an IC engine to generate electricity for sale does not appear to be financially feasible from our analysis of the available information. The cost of generating the electricity exceeds the revenue that would be generated from sales.

While it appears that direct use of the LFG for a greenhouse project may be feasible at the Pike County Landfill, additional incentives can make the use of the LFG for a greenhouse even more desirable and may make the use of an IC engine feasible. For example:

- **Good Public Relations and Environmental Control** - Because they use an otherwise wasted resource and also help to prevent air pollution, LFG projects can provide significant positive public relations for the landfill owner. Even if the project is not economically attractive, non-monetary incentives may be enough reason to pursue LFG utilization.

- The Kentucky Division of Energy makes approximately $24,000 a year available to help fund biomass energy demonstration projects in Kentucky. LFGTE projects are eligible. The funding is from the U.S. Department of Energy's Southeastern Regional Biomass Energy Program. Projects are selected competitively: a match of at least 50 percent funding from non-Federal sources is required.

  Contact: Mr. Geoffrey Young
  Kentucky Division of Energy
  (502) 564-7192, or in Kentucky (800) 282-0868
  Fax 502-564-7484
  E-mail: geoffreyyoung.@mail.state.ky.us

- **Tax Credits or Grants** - If tax credits are available from the government, the economics for LFG recovery can improve substantially. An example of these are tax credits for generating power from "clean" or renewable fuels, or for installing environmental controls that are more stringent than those required by law. Currently, these types of incentives for LFG have been proposed by Congress and the administration and are pending approval. If such incentives become available in the future, they could greatly enhance the profitability of LFG project development.

Since a greenhouse located in Kentucky is unlikely to require gas heating year-round, the operators of the Pike County Landfill may wish to explore additional ways in which LFG could be used in the warmer months. One particularly promising approach that has been implemented elsewhere is the installation of craft studios for glass-blowing and pottery. In the summer, when LFG is not useful for warming a greenhouse, it could be used as an energy source to power glass furnaces and/or pottery kilns. Two other applications of LFG that are currently being explored include powering a cold storage chiller for local produce and fueling a firefighter training facility.

Additional information about powering craft studios can be obtained by contacting Stan Steury at the Blue Ridge Resource Conservation and Development Council, Inc., an organization that has pioneered the use of LFG for this purpose. Contact information is as follows:

Blue Ridge Resource Conservation and Development Council, Inc.
Attn: Stan Steury
1081-2 Old U.S. 421
Sugar Grove, NC 28679

(828) 297-5805
(828) 297-5928 (fax)
blueridge@skybest.com

SECTION 4

ENVIRONMENTAL BENEFITS

In addition to being a potentially valuable resource for energy production, landfill gas is also considered an air pollutant. Landfill gas contains methane, a potent greenhouse gas. In terms of its heat retention capacity, methane is approximately 21 times more potent than carbon dioxide. In other words, one unit of methane can retain 21 times more heat than the same unit of carbon dioxide (CO_2). As our society continues to be concerned about the possibility that human activities and industry could accelerate global warming, attention has been focused on ways to reduce emissions of greenhouse gases. Utilizing LFG for energy is one way to mitigate those harmful effects.

LANDFILL GAS METHANE REDUCTIONS

Landfill gas recovery projects provide a decrease in overall greenhouse gas emissions from landfills because the methane is burned rather than being released. The end uses reviewed in this report (electricity generation, use as fuel to heat a greenhouse, transfer to a natural gas pipeline) would also destroy most of the non-methane organic compounds found in LFG.

The estimated amount of LFG combusted in the greenhouse application is 230 scfm, at 50 percent methane. During periods when the greenhouse is not being heated, this gas would be burned in the flare. Based on this gas combustion rate:

- Methane reduction = 1,160 Mg methane per year
- This is equivalent to a greenhouse gas reduction of 24,400 Mg CO_2 per year.
- This is equivalent to taking 6,110 cars off the road or planting 8,250 acres of forest per year.

For both the IC engines option and the medium-Btu gas pipeline option, we assumed that an average of 300 scfm of LFG would be consumed over the life of the project. A gas utilization of approximately 300 scfm would lead to the following methane reduction:

- Methane reduction = 1,520 Mg methane per year.
- This is equivalent to a greenhouse gas reduction of 31,820 Mg CO_2 per year.
- This is equivalent to taking 8,420 cars off the road or planting 11,380 acres of forest per year.

AVOIDED EMISSIONS

Additional benefits are obtained through the use of the methane in the LFG because it displaces the other fuels that would have otherwise been used to generate that energy. The use of LFG to heat the greenhouse displaces the use of natural gas. The use of LFG to generate electricity displaces other fossil fuel sources supplied to the Kentucky energy grid. The transfer of the LFG to the natural gas pipeline also displaces the use of natural gas. The avoided emissions for each of these cases are presented below.

Greenhouse Heating

Greenhouse gas emissions from natural gas combustion are only avoided when LFG is used to heat the greenhouse. The greenhouse would not need to be heated year-round and may only need to be heated for as little as 6 months per year. Therefore, the avoided emissions may range from 1,750 Mg of CO_2 per year (for 6 months of heating) to 3,300 Mg of CO_2 per year (for heating year-round). This is equal to the energy needed to heat between 900 and 1,800 U.S. homes.

Electricity Generation

By using the otherwise wasted methane contained in the collected LFG to generate electricity, fuels such as oil and coal that typically provide fuel for electricity generation are displaced. To calculate avoided CO_2 and sulfur dioxide (SO_2) emissions, we used the EGRID2000 database to determine the amounts of CO_2 and SO_2 emissions per Megawatt hour from energy generation for the mix of fuels and power generation techniques used by the landfill's electricity supplier, Kentucky Power Company. The annual emissions avoided by using LFG to generate electricity with an IC engine are presented below.

- CO_2 Emissions Avoided = 6,360 Mg per year.
- SO_2 Emissions Avoided = 60 Mg per year.
- This would offset the use of 190 railcars of coal or 89,550 barrels of oil per year.
- The potential kilowatts that can be produced by these IC engines could power 615 U.S. homes.

Transfer to Natural Gas Pipeline

The greenhouse gas emissions that are avoided by transferring the LFG to a natural gas pipeline are as follows:

- CO_2 Emissions Avoided = 4,300 Mg of CO_2 per year.
- This is equal to the annual energy needed to heat 2,350 U.S. homes.

SECTION 5

NEXT STEPS TO PROJECT DEVELOPMENT

This section identifies some of the next steps for moving forward on project development. LMOP can provide assistance related to many of these steps as listed below.

IDENTIFY ENERGY END USER

Pike County is discussing the medium Btu gas sale option with a developer. The natural gas pipeline that may accept the LFG is owned by Equitable Gas, a division of Equitable Resources (http://www.equitablegas.com). Further discussion with these parties is needed to fully analyze the medium Btu gas sales option. If Pike County is interested in further investigating the greenhouse option, they could contact LMOP industry partners with expertise in LFG greenhouse applications or the Blue Ridge Resource Conservation and Development Council contact listed in Section 3 of this report.

ESTABLISH PROJECT STRUCTURE

This type of project can be structured in a variety of different ways. The most common is to solicit for a third party developer. The landfill would send out an RFP to solicit bids from third party developers. The landfill could accept the best bid received to develop the project. However, projects have also been developed where the landfill owner has developed and managed the project internally. Under this plan, the landfill manager develops partnerships with equipment suppliers and the energy end user.

PERFORM MORE DETAILED FEASIBILITY EVALUATION

Because of the uncertainty in LFG flow rate, it would be prudent to install the gas collection system before entering into any agreements to sell the gas. This will allow site personnel, through the use of specialized equipment (GEM 500, ADM 870, etc.), to accurately measure the amount of LFG available for use. Also, it will be important to look at project economics more carefully to include site-specific interest rates, prices, and any local or federal government incentives that may be available. If the landfill owners decide to investigate the option of injecting the medium-Btu LFG into a gas pipeline, they should obtain firm, written criteria the LFG must meet for injection into the gas pipeline. Any investigation of this option should then include any additional costs for further treatment and processing of the LFG prior to injection. The developer may perform such an evaluation.

DRAFT DEVELOPMENT CONTRACT

Once the project structure is determined, a draft development contract is recommended. This contract would determine gas rights, rights to any emission reduction benefits, and the responsibilities of different partners for the different components of the project (e.g., design, installation, environmental compliance, and operation and maintenance).

ASSESS FINANCING OPTIONS

There are a variety of options for financing projects, including the potential for grants. Some of the options include:

- Private equity financing
- Project financing
- Municipal bonds
- Direct municipal bonds
- Grants/Loans
- REPI – Renewable Energy Production Incentive

NEGOTIATE CONTRACT

The sale of LFG is not a typical business transaction for landfill owners. Therefore, a third party developer or an attorney that specializes in this work typically negotiates the LFG sales contract. Some of the steps that will take place include:

- Preparing a draft offer contract.
- Determining the LFG needs.
- Developing project design and pricing.
- Preparing and presenting bid package.
- Reviewing contract terms and conditions.
- Signing contract.

The final steps include securing permits and approvals, contracting for engineering, installing the project, and starting up operations.

Please see Appendix D for a more detailed outline of next steps.

APPENDIX A

EMCON GAS GENERATION MODEL OUTPUT

Please note that this model, like any other mathematical projection, should be used only as a tool, and not an absolute declaration of the rate of LFG generation. Fluctuations in the rate and types of incoming waste, site operating conditions, refuse moisture and temperature may provide substantial variations in the actual rates of LFG generation and recovery.

This model has been prepared under the current standards of engineering practice, and is based upon the information available at the time of development. No other guarantees, either implied or expressed, are warranted.

LANDFILL GAS GENERATION MODEL INPUT SUMMARY
Pike County

General Information

Analysis performed by:	Juene Franklin
Project number:	821291
Date of analysis:	09/06/01

Analysis Timeframe

Opening year of the landfill:	1993
Closing year of the landfill:	2010
Analysis performed through the year:	2040

Site Operating Conditions

Refuse moisture condition:	Moderately Wet
Refuse temperature:	100 °F
Average compacted refuse density:	1,200 lb/cy

LFG System Recovery Efficiency

ID Number	Recovery Efficiency	Effective Period
1	85%	1993-2040

Waste Stream Composition

Component	Composition 1	Composition 2
Organics		
Food waste	9.0%	N/A
Garden waste	19.0%	N/A
Paper waste	33.0%	N/A
Other organics	7.0%	N/A
Organic Subtotal	68.0%	N/A
Inorganics	32.0%	N/A
Total	100.0%	N/A

Generation Rate Properties

Rapid subgroup conversion time:	4 yrs
Intermediate subgroup conversion time:	30 yrs
Slow subgroup conversion time:	100 yrs

EPA Modeling Parameters

Methane generation potential (L_o):	3,531 ft^3/Mg
Methane generation rate (k):	0.04 l/yr
NMOC concentration (C_{NMOC}):	595 ppmv

Summary of Results
Pike County
821291

Year	Annual Refuse Acceptance Rate (tons)	Cumulative Refuse Acceptance Rate (tons)	Upper limit of LFG Generation Rate (scfm)	Lower limit of LFG Generation Rate (scfm)	Upper limit of LFG Recovery Rate (scfm)	Lower limit of LFG Recovery Rate (scfm)	Average LFG Energy Rate (MMBtu/hr)
1993	88,812	88,812	0	0	0	0	0
1994	48,456	137,268	17	11	15	10	0
1995	52,128	189,396	31	21	26	18	1
1996	41,692	231,088	54	36	46	31	1
1997	60,128	291,216	86	57	73	49	2
1998	60,160	351,376	129	86	109	73	3
1999	56,511	407,887	177	118	150	100	5
2000	62,918	470,805	224	149	190	127	6
2001	68,834	539,639	265	177	225	150	7
2002	58,000	597,639	302	201	257	171	8
2003	58,000	655,639	339	226	288	192	9
2004	58,000	713,639	375	250	319	212	10
2005	58,000	771,639	409	273	348	232	11
2006	58,000	829,639	439	293	373	249	11
2007	58,000	887,639	467	311	397	264	12
2008	58,000	945,639	491	327	417	278	13
2009	58,000	1,003,639	511	341	435	290	13
2010	58,000	1,061,639	530	353	450	300	14
2011			548	365	466	310	14
2012			553	369	470	313	14
2013			554	369	471	314	14
2014			547	365	465	310	14
2015			529	353	450	300	14
2016			500	333	425	283	13
2017			463	309	393	262	12
2018			422	282	359	239	11
2019			386	257	328	218	10
2020			355	237	302	201	9
2021			327	218	278	185	8
2022			301	201	256	171	8
2023			277	185	236	157	7
2024			255	170	217	145	7
2025			235	157	200	133	6
2026			217	144	184	123	6
2027			200	133	170	113	5
2028			184	123	156	104	5
2029			170	113	144	96	4
2030			156	104	133	89	4
2031			144	96	122	82	4
2032			133	88	113	75	3
2033			122	82	104	69	3
2034			113	75	96	64	3
2035			104	69	88	59	3
2036			96	64	82	54	2
2037			89	59	75	50	2
2038			82	55	70	46	2
2039			76		64	43	2
2040			70	47	59	40	2

APPENDIX B

E-PLUS MODEL OUTPUT

E-Plus Analysis

Summary Report

Landfill: Pike County Landfill

Design Scenario: Power Generation

Author: Juene Franklin

Date: October 31, 2001

This assessment was performed using E-PLUS, Version 2.0 Beta. Analyses performed using E-PLUS are considered preliminary and are to be used for guidance only. It is imperative that a detailed final feasibility assessment be conducted by qualified landfill gas recovery and utilization professionals prior to preparing a design, initiating construction, purchasing materials, or entering into agreements to provide or purchase energy from a landfill gas project.

Summary Results

Based on the project definition, landfill characteristics, and financial assumptions provided, the following summary results are estimated:

Project Start Year:	2001
Project Lifetime:	15
Electricity Capacity:	933 kW for electricity sales
Average Electricity Price:	$0.0562 per kWh, averaged over the life of the project
Gas Sales Capacity:	0 MMBtu/year for gas sales
Average Gas Price:	$0.00 per MMBtu, averaged over the life of the project

Financial Results:

Net Present Value:	$- 515,303
IRR:	0
Simple Payback:	35.0 years
Capital Costs:	$ 1,497,305
O&M Costs:	$ 196,230 per year, averaged over the life of the project

These financial results include the costs associated with the gas collection and flaring system. As defined, the landfill does not trigger the recently promulgated NSPS/EG emissions control requirements using the Tier 1 calculation method.

Landfill Characteristics

Open Year:	1993
Close Year:	2010
Current Year:	2001
Waste in Place:	539,639 tons, in 2001
Waste Acceptance Rate:	62,400 tons per year, from current year onward
Depth:	150 feet, maximum during landfill lifetime
Area:	24 acres, maximum during landfill lifetime

Gas Generation and Collection

Gas Generation from 1993 to 2036:

Annual Average:	75 mmcf/year of methane
	150 mmcf/year of landfill gas
Maximum:	124 mmcf/year of methane
	249 mmcf/year of landfill gas

Gas Generation During the Project: 2001 to 2016:

Annual Average:	100 mmcf/year of methane
	200 mmcf/year of landfill gas
Maximum:	124 mmcf/year of methane
	249 mmcf/year of landfill gas

Gas Collection Efficiency: 85 percent

Financial Assumptions

Project Start Year:	2001
Project End Year:	2016
Base Year for NPV Estimate:	2001

Downpayment Percent:	20 percent of total capital costs (remainder is borrowed)
Loan Rate:	8 percent
Loan Period:	10 years
Project Discount Rate:	12 percent
Marginal Tax Rate:	0 percent
Depreciation Method:	Straight Line
Inflation Rate for Costs:	2.0 percent per year
Collect and Flare Costs:	The costs associated with the gas collection and flaring system are included from the financial analysis.

Project Configuration Summary

Collection:	Included
Flare:	Included
Gas Treatment:	Included
Compression:	Included
Gas Enrichment:	Not Included
Electricity Production:	
Generation:	Included
Intertie:	Included
Sales	Included
Gas Production:	
Pipeline:	Not Included
Sales:	Not Included

Electricity Production and Sales Summary

Total Capacity:	933 kW
Average Generation:	6,213,222 kWh/year over the life of the project
Engine Load Factor:	76.00 percent over the life of the project
Average Electricity Price:	$0.0562 per kWh, averaged over the life of the project

Gas Production and Sales Summary

Gas Sales Capacity:	0 MMBtu/year for gas sales
Average Gas Price:	$0.00 per MMBtu, averaged over the life of the project
Average Production:	0 MMBtu/year over the life of the project

Price Analysis

Electricity Price: To achieve an IRR equal to the project evaluation discount rate of 12 percent, an average electricity price of $0.0557 per kWh is needed, average over the life of the project (assuming that the price for gas sales, if any, remains as defined in the project specification).

Gas Price: To achieve an IRR equal to the project evaluation discount rate of 12 percent, an average gas price of

$30.00 per MMBtu is needed, average over the life of the project (assuming that the price for electricity sales, if any, remains as defined in the project specification).

E-Plus Analysis

Summary Report

Landfill: Pike County Landfill

Design Scenario: LFG Sale

Author: Juene Franklin

Date: October 31, 2001

This assessment was performed using E-PLUS, Version 2.0 Beta. Analyses performed using E-PLUS are considered preliminary and are to be used for guidance only. It is imperative that a detailed final feasibility assessment be conducted by qualified landfill gas recovery and utilization professionals prior to preparing a design, initiating construction, purchasing materials, or entering into agreements to provide or purchase energy from a landfill gas project.

Summary Results

Based on the project definition, landfill characteristics, and financial assumptions provided, the following summary results are estimated:

Project Start Year: 2001

Project Lifetime: 15

Electricity Capacity: 0 kW for electricity sales

Average Electricity Price: $0.0000 per kWh, averaged over the life of the project

Gas Sales Capacity: 50,262 MMBtu/year for gas sales

Average Gas Price: $2.50 per MMBtu, averaged over the life of the project

Financial Results:

Net Present Value: $ 486,508

IRR: 45

Simple Payback: 6.6 years

Capital Costs: $ 528,970

O&M Costs: $ 51,476 per year, averaged over the life of the project

These financial results include the costs associated with the gas collection and flaring system. As defined, the landfill does not trigger the recently promulgated NSPS/EG emissions control requirements using the Tier 1 calculation method.

Landfill Characteristics

Open Year: 1993

Close Year: 2010

Current Year: 2001

Waste in Place: 539,639 tons, in 2001

Waste Acceptance Rate: 62,400 tons per year, from current year onward

Depth: 150 feet, maximum during landfill lifetime

Area: 24 acres, maximum during landfill lifetime

Gas Generation and Collection

Gas Generation from 1993 to 2036:

Annual Average: 75 mmcf/year of methane
150 mmcf/year of landfill gas

Maximum: 124 mmcf/year of methane
249 mmcf/year of landfill gas

Gas Generation During the Project: 2001 to 2016:

Annual Average: 100 mmcf/year of methane
200 mmcf/year of landfill gas

Maximum: 124 mmcf/year of methane
249 mmcf/year of landfill gas

Gas Collection Efficiency: 85 percent

Financial Assumptions

Project Start Year:	2001
Project End Year:	2016
Base Year for NPV Estimate:	2001

Downpayment Percent:	20 percent of total capital costs (remainder is borrowed)
Loan Rate:	8 percent
Loan Period:	10 years
Project Discount Rate:	12 percent
Marginal Tax Rate:	0 percent
Depreciation Method:	Straight Line
Inflation Rate for Costs:	2.0 percent per year
Collect and Flare Costs:	The costs associated with the gas collection and flaring system are included from the financial analysis.

Project Configuration Summary

Collection:	Included
Flare:	Included
Gas Treatment:	Included
Compression:	Included
Gas Enrichment:	Not Included
Electricity Production:	
Generation:	Not Included
Intertie:	Not Included
Sales	Not Included
Gas Production:	
Pipeline:	Included
Sales:	Included

Electricity Production and Sales Summary

Total Capacity:	0 kW
Average Generation:	0 kWh/year over the life of the project
Engine Load Factor:	0.00 percent over the life of the project
Average Electricity Price:	$0.0000 per kWh, averaged over the life of the project

Gas Production and Sales Summary

Gas Sales Capacity:	50,262 MMBtu/year for gas sales
Average Gas Price:	$2.50 per MMBtu, averaged over the life of the project
Average Production:	42,444 MMBtu/year over the life of the project

Price Analysis

Electricity Price: To achieve an IRR equal to the project evaluation discount rate of 12 percent, an average electricity price of $0.0000 per kWh is needed, average over the life of the project (assuming that the price for gas sales, if any, remains as defined in the project specification).

Gas Price: To achieve an IRR equal to the project evaluation discount rate of 12 percent, an average gas price of

$1.26 per MMBtu is needed, average over the life of the project (assuming that the price for electricity sales, if any, remains as defined in the project specification).

APPENDIX C

COST SUMMARY TABLE USING EMCON'S PRO FORMA MODEL

LMOP FEASIBILITY STUDY FOR GREENHOUSE HEATING OPTION
PIKE COUNTY LANDFILL

Description - Greenhouse			GCCS Included
Size - Base Unit & Add On Unit			22 x 96
Area			2,112
No. of Base Units			1
No. of Add On Units			38
Heating requirements	Btu/hr.		6,900,000
Fuel requirement @ 50% CH4	scfm		230
Capital Costs			
Equipment Quote			738,882
Shipping, duties, insurance etc.			
Unloading			
Subtotal			738,882
Installation			
Mfg. Installation Allowance			808,392
Contingency		15%	121,259
Subtotal			929,651
Financing Costs			50,000
			3%
Total Installed Cost			$ 1,718,533
Cost per SF of Greenhouse Space			$ 20.86
All-In Cost including Gas Collection Control System			
Installed Cost of Facility			$ 1,718,533
Installed cost of GCCS			526,249
			$ 2,244,782
Amortization of Capital			
term in years	10		334,539
rate		8%	
Annual Gas collection System O&M Cost			35,000
Annual Facility O&M Cost			-
Total Annual Cost			369,539

$$\boxed{\left[\frac{\$113{,}400}{year}\right]\left[\frac{year}{525{,}600\min}\right]\left[\frac{\min}{230\,ft^3 LFG}\right]\left[\frac{ft^3 LFG}{500 Btu}\right]\left[\frac{10^6\,Btu}{MMBtu}\right]}$$

per MMBtu **$ 1.876**

LMOP FEASIBILITY STUDY FOR GREENHOUSE HEATING OPTION (CONTINUED)
PIKE COUNTY LANDFILL

Gas Collection Control System Cost

Gas Collection System per E-Plus		501,249	estimate
Less: Well drilling (wells in place)		-	
			501,249
Add: 1000 feet of 6" HDPE pipe to Facility			22,000
Add: Allowance for tees and valves to divert gas to flare			3,000
Total Capital Cost			526,249
Amortization of Capital Cost			
term in years	10		78,427
rate	8%		
Annual Gas collection System O&M Cost			35,000
			$ 113,427

LMOP FEASIBILITY STUDY
PIKE COUNTY LANDFILL
Financial Summary for EMCON PRO FORMA Analysis for all 3 options

	Results at Sale Price of $0.05 per kWh.	Sale Price required to Yield 12 % IRR
	2 - 335 kW Recip Gensets	2 - 335 kW Recip Gensets
Electricity Generation		
Electricity Sale Price / kWh	**$ 0.0500**	**$ 0.0701**
Landfill Gas Purchase Price per MMBtu	$ -	$ -
Production Capacity in kW	670	670
Capital Cost - including GCCS	$ -	$ -
Annual Operations & Maintenance Cost	$ -	$ -
Loan Rate	8.0%	8.0%
Loan Period	10 Years	10 Years
Discount Rate	7.0%	7.0%
Inflation rate for Costs	2.0%	2.0%
Net Present Value	$ (556,800)	$ 76,103
Internal Rate of Return	n/a	12.0%
Simple Payback	> 15 Years	6 Years

Gas Supply to Greenhouse

Cost of GCCS and Pipelines to Greenhouse	$ 526,000

$$\left[\frac{\$113,400}{year}\right]\left[\frac{year}{525,600\min}\right]\left[\frac{\min}{230ft^3LFG}\right]\left[\frac{ft^3LFG}{500Btu}\right]\left[\frac{10^6Btu}{MMBtu}\right]$$

Amortization of capital @ 8%, 10 years.	$ 78,400
Annual Gas Collection System O&M Cost	35,000
Total Annual Cost	$ 113,400
Cost of LFG to Greenhouse	**$ 1.88** per MMBtu

Cost of LFG Calculation

Gas Supply to Pipeline - Medium Btu

Cost of LFG Calculation

Cost of GCCS and Pipeline to Delivery Point	$652,000

$$\left[\frac{\$196,900}{year}\right]\left[\frac{year}{525,600\min}\right]\left[\frac{\min}{300ft^3LFG}\right]\left[\frac{ft^3LFG}{500Btu}\right]\left[\frac{10^6Btu}{MMBtu}\right]$$

An	97,200
A	99,700
Total Annual Cost	$196,900

Cost of LFG to Delivery Point	**$ 2.50**	per MMBtu

APPENDIX D

STEPS TO LANDFILL GAS-TO-ENERGY PROJECT DEVELOPMENT

FOLLOW THESE STEPS TO LANDFILL GAS-TO-ENERGY PROJECT DEVELOPMENT

Let the LMOP work with you through each step of Landfill Gas-to-Energy Project Development

- Determine who your LMOP representative is
- Join LMOP's outreach or partner program
- Work with LMOP representative at each phase of project development

1. Estimate LFG Recovery Potential and Perform Initial Assessment or Feasibility Study

Desired Landfill Characteristics:

- Landfill is a MSW landfill
- Landfill has at least 1 million tons of MSW in place
- Landfill is at least 30 feet deep
- Site receives greater than 25 inches of rainfall annually
- Landfill has an existing gas collection system

Helpful LMOP Tools:

- LandGEM or EPLUS software
- Project Development Handbook

2. Evaluate Project Economics

Identify Energy End Users/Sales:

- On-site use (gas and electric)
- Nearby direct gas use
- Electricity use
- High-Btu upgrade (sales to nearby customers or gas utility)
- Specialty use (greenhouse, vehicle fuel, kilns)

Helpful LMOP Tools:

- Project Development Handbook
- EPLUS software

3. Establish Project Structure

Identify Who Will Develop/Manage the Project:

- Option 1: Develop/manage the project internally
- Option 2: Team with a project developer
- Option 3: Team with a partner (equipment supplier, energy end user, community)

Finding a Development Partner:

- Issue a Request for Proposals
- Acquire expressions of interests
- Solicit developers
- Negotiate with vendors

Helpful LMOP Tool:

- Industry ally list for reference, advice and distribution of RFPs

4. Draft Development Contract

- Determine gas rights
- Determine rights for potential emission reductions
- Determine partner responsibilities, i.e.:
  - design
  - installation
  - operation and maintenance

Helpful LMOP Tool:

- Project Development Handbook

5. Determine Financing Options

- Private equity financing
- Project financing
- Municipal bonds
- Direct municipal funds
- Grants
- REPI – Renewable Energy Production Incentive

Helpful LMOP Tools:

- Federal, foundation, and state grant guide
- State primers

6. Negotiate Energy Sales Contract

- Prepare draft offer contract
- Determine utility need for power
- Develop project design and pricing
- Prepare and present bid package
- Review contract terms and conditions
- Sign contract

7. Secure Permits and Approvals

Regulations:

Solid waste permit

- Air permit
- Local permitting issues
- Right-of-ways and easements

Procedures:

- Contact and meet regulatory authorities to determine requirements
- Educate about benefits of project and seek approval from landfill neighbors, local officials, and local environmental and public interest groups
- Assemble information, perform calculations and designs
- Submit complete permit applications to regulatory agencies
- Amend permit application (as needed)

Helpful LMOP Tools:

- NSPS Permit Guide
- State primers
- Community Outreach Primer

8. Contract for Engineering, Procurement & Construction, and Operation & Maintenance (EPC/O&M) Services

- Owner/developer solicits bids from EPC/O&M contractors
- Owner/developer selects EPC/O&M contractor
- Owner/developer negotiates contracts
- EPC/O&M contractor conducts engineering design, site preparation, plant construction
- EPC contractor/developer conducts start-up testing

9. Install Project and Start Up Commercial Operation

- Ribbon cutting
- Public tours
- Press releases

Helpful LMOP Tools:

- Marketing and Promotion Primer
- Community Outreach Brochure

Potential Benefits Gained By Landfill Owners/Operators From LFGTE

Economic

Revenue shares from the sale of landfill gas or electricity produced

- Typical revenue for electricity = $0.03/kWh to $0.05/kWh
- Typical revenue for gas = $2.00/MMBtu to $4.00/MMBtu
- REPI[1] payments (municipal owners only) = 1.5 cents per kWh
- Royalty payments for gas extraction (private developer only) = varies

Offset the cost of a LFG collection/ control system

- Typical capital costs (1 million ton landfill) = $600,000 - $750,000
- Typical O&M costs (1 million ton landfill) = $40,000 - $50,000/yr

Market potential

- LFG = $2.00/ MMBtu (avg.) vs. natural gas = $3.00/ MMBtu vs. propane = $8.00/ MMBtu (avg.)

Other Areas of Revenue

- Emissions reductions
- Green power/green marketing program

Environmental

- Improve local air quality
- Lower risk of global climate change
- Reduce emissions from fossil fuels
- Subsurface migration control

Community Image

- Progressive, innovative resource usage
- Responsible community planning
- Safer landfill with reduced odors
- Job creation through project development
- Improved economic development near the landfill

Energy

- Reliable, local fuel source
- Less need for use of polluting fossil fuels

One Million Tons of Waste Yields Considerable Benefits

- 1 million tons of waste in place would typically generate 300 cubic feet per minute (cfm) of landfill gas, which could then generate 7,000,000 kilowatt hours (kWh) per year.
- 7,000,000 kilowatt hours (kWh) is enough energy to power 700 homes for a year.
- In terms of reducing greenhouse gas emissions, utilizing 300 cfm/year of landfill gas yields the same environmental benefit as removing 6,100 cars from the road for one year.
- Similarly, utilizing 300 cfm/year has the same environmental impact as planting 8,300 acres of trees.